MICROCONTROLLER BASED RATIO CONTROL FOR ELECTRO-MECHANICAL DUAL ACTING PULLEY CONTINUOUSLY VARIABLE TRANSMISSIONS

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Dedicated to:

My beloved parents:
Slamet Mudjihardjo
Nur Chofifah

My beloved parents in law:
Alm. Sidiek Rochmanto
Sumiati

My beloved wife:
Septi Dwi Jayanti

My brother:
Hendra Kurniawan

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ABSTRACT

Electro-Mechanical Dual Acting Pulley Continuously Variable Transmission (EMDAP CVT) is a transmission operated by electro-mechanical actuated system. It has a potential to reduce energy consumption where power is only needed during changing of CVT ratio and no additional power is needed to maintain the CVT ratio due to self-lock mechanism design feature of the EMDAP CVT. In this research, simulation of an EMDAP CVT model was first performed in order to evaluate controller system performance using MATLAB/Simulink software package. Then, confirmation of the simulation results is made by experimental data that is being measured from EMDAP CVT test rig. In order to obtain adequate performance, basic Proportional Integral Derivative (PID), Proportional Derivative (PD) and Proportional Derivative with Conditional Integral (PDCI) controller schemes were proposed to control EMDAP CVT ratio. Relay feedback and Ziegler-Nichols methods were utilized to tune the PID based controller parameters. From simulation analysis, the basic PID based controller shows a huge overshoot up to 280% and it takes very long settling time up to 65 seconds. However, this controller generates very small steady state error which is around 0.2%. The PD controller shows better performance where there is no overshoot occurred and faster settling time, i.e. 8 seconds, but steady state error is a bit higher, i.e. 3.2%, than the basic PID based controller. The best performance is predicted by PDCI controller where it shows maximum overshoot at 0.2%, 8 seconds in settling time and steady state error at 0.1%. In the experimental work, only PD and PDCI controller schemes are adopted because of their good control performance in the simulation. It is found that performance of the PD and PDCI controllers in the experiments are quite close to those predicted in the simulation. For the PD controller, experimental results show no overshoot, it takes only 4 seconds in settling time and produces steady state error of 10%. As for the PDCI controller, it shows 1% in maximum overshoot, 8 seconds in settling time and steady state error at 1%. This indicates that the PDCI controller is superior than the PD controller in terms of steady state error and this is confirmed by simulation and experimental results.

ABSTRAK

Takal Dwi Tindakan Elektro-Mekanikal Transmisi Sentiasa Berubah (EMDAP CVT) adalah transmisi yang dikendali oleh sistem penggerak elektro-mekanikal. Ia mempunyai potensi untuk mengurangkan penggunaan tenaga di mana, kuasa hanya diperlukan semasa penukaran nisbah CVT dan tiada kuasa tambahan diperlukan untuk mengekalkan nisbah CVT disebabkan oleh ciri rekabentuk mekanisma terkunci sendiri bagi EMDAP CVT. Dalam kajian ini, kerja-kerja simulasi bagi model EMDAP CVT dilakukan terlebih dahulu bagi menilai prestasi sistem kawalan menggunakan pakej perisian MATLAB/Simulink. Seterusnya, pengesahan keputusan simulasi dibuat melalui keputusan eksperimen yang diperoleh daripada pelantar ujian EMDAP CVT. Dalam usaha untuk mendapatkan prestasi yang mencukupi, skim pengawal asas PID, PD dan PDCI dicadangkan untuk mengawal nisbah EMDAP CVT. Kaedah *relay feedback* dan *Ziegler-Nichols* digunakan untuk melaras parameter pengawal PID. Daripada analisis simulasi, pengawal asas PID menunjukkan lajakan besar berlaku sehingga 280% dan ia mengambil masa pengenapan yang sangat panjang sehingga 65 saat. Bagaimanapun, pengawal jenis ini hanya menjana ralat keadaan mantap yang sangat kecil iaitu 0.2%. Pengawal PD pula menunjukkan prestasi yang lebih baik dengan tiada lajakan terhasil dan masa pengenapan yang lebih cepat iaitu 8 saat, namun, ralat keadaan mantap adalah sedikit besar iaitu 3.2% daripada pengawal asas PID. Prestasi terbaik diramal oleh pengawal PDCI di mana ia menunjukkan lajakan maksimum pada 0.2%, 8 saat masa pengenapan dan ralat keadaan mantap pada 0.1%. Di dalam kerja-kerja eksperimen, hanya skim pengawalan PD dan PDCI yang digunapakai kerana ia memberikan prestasi kawalan yang baik di dalam simulasi. Didapati bahawa prestasi pengawal PD dan PDCI di dalam eksperimen hampir menyamai apa yang diramal di dalam simulasi. Bagi pengawal PD, keputusan eksperimen menunjukkan tiada lajakan berlaku, ia hanya mengambil 4 saat masa pengenapan dan menghasilkan ralat keadaan mantap sebanyak 10%. Bagi pengawal PDCI, keputusan eksperimen menunjukkan 1% dalam lajakan maksimum, 8 saat masa pemendapan dan ralat keadaan mantap pada 0.1%. Ini menunjukkan bahawa pengawal PDCI adalah lebih baik daripada pengawal PD berdasarkan ralat keadaan mantap dan ini disahkan oleh keputusan simulasi dan eksperimen.